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CRITIQUE OF A PROCESS PROPOSED TO DETERMINE CF AIRCREW/COCKPIT COMPATIBILITY

prepared for

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1.0 BACKGROUND REVIEW

1.1 Introduction

The Defence and Civil Institute for Environmental Medicine (DCIEM) is currently undertaking an aircrew/cockpit compatibility evaluation (ACCE), the purpose of which is to review Canadian Forces (CF) aircrew selection standards so as to ensure that they provide for adequate physical compatibility between aircrew and aircrew stations. One particular phase of this tasking requires the development of a process for evaluating aircrew/cockpit compatibility within the Canadian Forces. Such an evaluation process has been developed using a computer man-modelling package known as a System for Aiding Man/Machine Interaction Evaluation, or SAMMIE (Matthews, Greaves and Rothwell, 1985).

The application of the SAMMIE man-modelling package presumes that a process exists, or can be created, that allows the appropriate crew station geometry and crew anthopometry parameters to be manipulated in such a way that any conflicts, in terms of visual requirements, functional reach, or clearance be identified. In the proposed ACCE process, the SAMMIE software is used to manipulate these anthropometric parameters. The output is represented as a series of two-dimensional planar envelopes constituting the limiting values of relevant anthropometric parameters for each aircraft crew station.

In this report, the currently proposed ACCE process (Matthews, Greaves and Rothwell, 1985) is critiqued. Discussion has been limited to the issues of vision, reach and clearance. Other background information that pertains to this process, eg. anthropometrics, has been briefly described in the Appendices.

2.0 CRITIQUE OF THE ACCE PROCESS

2.1 Introduction

The following critique focuses only on the criteria for vision, arm and leg reach, and leg clearance, all of which are evaluated for each particular aircraft crew station environment. The three different ACCE processes (fixed seat, fully adjustable seating and ejection seating) have been evaluated simultaneously, whenever possible, since in most instances, the same criteria exist for each process.

As is evident by this critique, the process as originally proposed has been judged inappropriate for either crew station limitation definition or for aircrew selection criteria. Difficulties with the original process have been outlined in this report and subsequent improvements have been suggested in order to make the process feasible. Where necessary, assumptions or implied criteria have been defined and justified.

Limitations that are inherent in the SAMMIE program, the digitized aircraft crew station data or the anthropometric CF aircrew data have not been considered in this report since they have no influence on the validity or non-validity of the ACCE process itself. However, ultimately, these limitations should not be overlooked since they may lead to difficulties in interpreting the results from executing the revised ACCE process.

2.2 Critique of the ACCE Vision Analysis

Two existing modules in the SAMMIE modelling system are available to evaluate field of vision. The sight module allows the crew station environment to be viewed as seen from the man-model's eyes. The visibility module allows a 360 degree flat representation of these views. Both modules are used to evaluate field of vision for a given aircraft crew station as well as for aircraft conformance to ASCC Vision Requirement Standards.

Comfort and absolute eye movement limits utilized in SAMMIE have been determined (Matthews and Rochford, 1986); however, these constraints cannot be altered by the user. Therefore, these limitations must be accepted as part of the existing SAMMIE program.

Quantification of the aircraft crew station has been accomplished by digitization of preselected primary features within the aircraft. It must be assumed that the most pertinent aircraft crew station features have been digitized. However, the benefits of this simplistic representation of the crew station may be overshadowed by the overall complexity of the actual aircraft crew station. It is possible that certain physical features not digitized may affect the man-model's field of vision in certain seating positions. At the same time, interruptions in the field of vision, caused by structures outside the aircraft, cannot be determined.

As an example, it is accepted practice by fighter aircraft pilots to maximize their outward vision by sitting as high as possible above the nose of the aircraft. If the nose portion of the aircraft is not adequately digitized then the seated height of the man-model derived from the vision analysis may be somewhat lower than the actual required seated height.

Operational requirements within the given aircraft crew station also appear to be an issue which has not been properly addressed. Field of vision analysis is restricted to within a 180 degree arc facing forward in the crew station. Most aircraft crew stations require that the operator be able to see over their shoulders or at least in arcs greater than 180 degrees. For this reason, field of vision evaluation within realistic head/neck motion constraints may be useful, especially as a means of detecting visual obstructions which would not be detected within the current 180 degree arc.

2.3 Critique of the ACCE Reach Analysis

There are eight separate parameters required in the ACCE reach analysis in order to determine whether aircrew/cockpit compatibility can be achieved in terms of the leg and arm reach. Five of these parameters are anthropometric in nature, namely buttock-knee length, knee height, seated height, anterior arm length, and bideltoid breadth. Although a discussion of anthropometry is beyond the scope of this report, assumptions regarding relationships between different anthropometric parameters will influence the results of a leg and arm reach analysis (as well as a leg clearance analysis). Appendix 'B' briefly discusses some of the relevant anthropometric considerations involved with the ACCE process.

The three remaining parameters are geometric and refer to the characteristics of the cockpit. They are horizontal location of the rudder pedal (including pedal travel), and both the horizontal and vertical location of the seat.

Within the current process, arm and leg reach analysis produces a series of two-dimensional criterion envelopes. These criterion envelopes assume that, for fixed values of certain independent parameters, all anthropometric variations are two parameter functions. This simplification is not necessary but is convenient for analysis purposes. If, for example, the functional arm reach was to depend on anterior arm length, bideltoid breadth and seated height, the envelope becomes a three dimensional surface rather than a simple plane. Should a fourth parameter, eg. seat location, be considered to be dependent, then the surface becomes four-dimensional. This result is not only difficult to visualize but also difficult to present on two-dimensional paper. Therefore, in practical terms, this method should be avoided.

2.4 Critique of the ACCE Leg Clearance Analysis

For the non-adjustable seat aircraft (ACCE Process A), it is assumed that leg clearance needs can be fully identified by establishing: (i) the maximum permissible knee height for the 99th percentile buttock-knee length, and (ii) the maximum permissible buttock-knee length for the 99th percentile knee height, when the pedals are fully away from the operator.

This assumes that leg clearance need only be assessed for long legs with the foot pedals as far away as possible. This is too restrictive, as marginal interferences which are found to occur under these conditions may very well be avoided at some other foot positions.

Secondly, fixing, for example the buttock-knee length L1, and finding the maximum value for sitting knee height L2 (and vice versa) does not provide a continuous description of the "clash profile". That is, it would be better to know how L1 and L2 vary over the entire range for which leg clearance is achieved.

For the fully-adjustable seat (ACCE Process B), the ability to manipulate L1 and L2 disappears altogether and leg length (approximately L1 plus L2) is the single independent variable. If variations in L1 and L2 for the same leg length are likely, then both variables must be incorporated in the process.

In Process 'B', the seat and pedals are positioned at various extremes under the presumption that interferences identified here are the critical cases. Clearly however, the maximum allowable leg lengths will likely be less than deduced if, in order to satisfy arm reach requirements, the seat must be positioned at an intermediate location. Thus, leg clearance requirements should, in general, also be assessed at intermediate seating/pedal configurations.

In Process 'C', for ejection seat aircraft, leg clearance is assessed in much the same way as in Process B with the additional requirement of leg clearance as the seat rides up the ejection rails. This is satisfactory except for the fact that the foot position is not defined. Furthermore, the maximum permissible L1 value might be a function of L2. The process can be simplified by creating a canopy bow plane (parallel to the seat rails) with which the knees should not interfere.

2.5 Other Considerations

It is understood that at the present time, the techniques and methods which form the basis of the ACCE process possess their own series of limitations and assumptions. The degree to which these limitations and assumptions influence the outcome of the process is not known at this time. Limitations of the SAMMIE model with respect to limb segment manipulation and seating capabilities are not well understood at this time. Similarly, the limitations of the anthropometric (and anthropomorphic) data as well as the crew station data must be appreciated, even if they cannot be fully understood. These limitations should be well documented prior to performing any ACCE evaluations.

It is believed that although these limitations may influence the outcome, they will not influence the validity of the process itself.

2.6 Critique Summary

1. The generation of two-dimensional criterion envelopes is based on the assumption that each criterion depends only on two parameters. Such envelopes may not always be so described. Such simplification is a matter of practical concern, thus, the validity of the criterion envelope should be tested with the model before it is assumed to be true.

2. The currently proposed process considers only limiting cases of crew station geometry. This can be misleading as critical geometries may occur at intermediate configurations. This may also lead to errors of interpretation when attempting to establish workstation limitations.

3. Unlimited manipulation of anthropometric parameters is unnecessary since anthropometric values would exceed normal human limits and the manipulation process itself would represent a considerable amount of processing time.

4. Specific limitations which are inherent to the SAMMIE model and the workstation data, will not inhibit the process' validity but may defeat the purpose of the proposed process and limit its generality.

3.0 THE REVISED PROCESS

3.1 Introduction

The following process was developed for fully adjustable aircraft given the assumption that both fixed seat and ejection seat aircraft represent specific cases nested within this more general approach. All procedures are outlined below and figures are provided to indicate typical workstation envelopes for a specific seating location.

Since anthropometry and crew station geometry are independent of each other, ie. the shape of a potential crew member is independent of the existing aircraft, the complexity of the criterion envelopes can be reduced by regarding each specific aircraft seat location as simply representing a specific crew station. Anthropometric parameter manipulation within each crew station environment thus reduces the number of parameters from eight to five. Each criterion that can be reduced to a function of one or two anthropometric variables can then be represented on a two-dimensional surface.

As mentioned in the critique, the manipulation of anthropometric parameters beyond normal human limits is unnecessary and represents a considerable amount of processing time. However, establishment of crewstation limitations does require that the process explore the outer boundaries of any given workstation, even though these boundaries may be well beyond human anthropometric limits. The currently revised process is unique in that it may be utilized as part of the candidate selection process or as a method to determine existing crewstation limitations.

The revised process proposes the use of an L1/L2 ratio which reflects the relationship between buttock-knee length L1 and sitting knee height L2. An analysis of the CF anthropometric data has found the mean L1/L2 ratio value to be 1.08 with a maximum ratio value of 1.17 and a minimum ratio value of 0.97. It should be emphasized that these ratios are estimates taken from a very finite population, namely CF aircrew males. More accurate L1/L2 ratio values may be derived from a larger population that includes both male and female anthropometric data. The plot from which the existing ratio was derived may be found in

Appendix 'C'.

Manipulation of the buttock-knee length and knee height parameters within these ratio limits maintains the resulting criterion envelopes within normal human anthropometric limits and thus eliminates a great deal of redundant or useless data.

Maximum and minimum values for certain anthropometric parameters are required to initiate this process; however, they have not been established at the present time since the process will operate regardless of the anthropometric parameters being considered. It would seem appropriate that the anthropometric parameters selected for this process should reflect the population for which the aircraft have been intended, typically that of the Canadian adult. It would be pointless to operate the process with anthropometric parameters which are outside this population unless physical workstation limitations are being established.

The operator of the process should select minimum values which approximate the smallest possible man-model within any given workstation. Maximum values may be selected as the largest possible man-model within the workstation. This is only applicable when the process is used for candidate selection. If the process is to be used for establishing crewstation limitations then no maximum exists, since the process must continue to evaluate the workstation until a physical limitation or a marginal interference occurs.

The term marginal interference refers to any contact (clash) made by the man-model during workstation evaluation. An acceptable value for marginal interference has not been established since this value must incorporate such factors as clothing worn, soft tissue deformation, joint flexibility, and reach capabilities while under restraint. Once again, the value prescribed for marginal interference only influences process resolution and not the process itself.

Similarly, in an effort to reduce the complexity of the work station analysis, the revised process makes the following assumptions with respect to certain anthropometric relationships:

(i) Functional arm reach depends only upon seated height and arm length. It is independent of bideltoid breadth when the operator is in an unrestrained position. Analysis of the CF aircrew data shows little or no relationship between bideltoid breadth and functional arm reach (see Appendix D). It is not possible to conclude as to whether or not this same relationship exists for workstation operators who are in a restrained position. Further study is necessary before this can be proven; however, in this instance it shall be assumed that this relationship holds true regardless of restraint condition, ie., unrestrained, partial restraint, full restraint.

(ii) Functional leg reach and leg clearance depend only upon buttock-knee length and knee height.

(iii) The limit of 20 degrees flexion at the knee is indicative of a normal posture while seated in an aircraft. This value has been selected as an arbitrary value and may or may not represent the optimal flexion angle for operating an aircraft. Biomechanical studies designed to evaluate muscular force generation at given joint angles would be required in order to validate this assumption.

(iv) Visual field and lateral upper body clearance limitations depend only upon seated height and bideltoid breadth.

It is recommended that the operator of the revised SAMMIE process have a fundamental knowledge of the above concepts as well as a thorough working knowledge of the SAMMIE man-modelling package. The operator must also be supplied with the proper maximum anthropometric parameters (where necessary). It would be expected that the computer software would be able to support the decision making processing that is found in the revised process flowcharts.

3.2 Revised Process Procedure

3.2.1 Leg Clearance Analysis

The same leg clearance analysis procedure is used for both ejection, and non-ejection aircrafts. In the case of ejection seat aircrafts; however, the maximum buttock - knee length L1 will be limited by ejection clearance requirements, in addition to the functional clearance requirements. Thus, an ejection aircraft upper leg clearance analysis should be carried out prior to the leg clearance analysis. The procedure is described here, and outlined in a flowchart (figure 2a).

Interference is most likely to occur when the buttock - knee segment is perpendicular to the ejection rail. The maximum L1 is determined by increasing the L1 length from its initial minimum value until interference with the ejection canopy occurs, or the normal human limit is exceeded (while the L1 segment is kept perpendicular to the ejection rails).

The procedure for leg clearance analysis is outlined below, and summarized in a flowchart (figure 2b).

All adjustments in segment lengths shall be in 1.0 cm increments unless otherwise stipulated. This value has been arbitrarily selected and represents only a suggested increment. A larger incremental value would require less iterations of the process although there would be an accompanying loss of process resolution.

Anthropometric values for the right and left limb segments are always manipulated concurrently.

1. Select an aircraft.

2. Select an initial seating/rudder pedal configuration, with the pedals in the neutral position.

3. For purposes of limiting unnecessary computations, establish maximum and minimum values for all anthropometric measures for the population under consideration. Establish also the maximum and minimum values for the ratio of L1 to L2 (suggested values are 1.17 and 0.97 respectfully).

4. Set initial values for each of the following anthropometric variables:

   (i) Buttock-knee length L1 to a minimum value.

   (ii) Knee height L2 to L1/1.08. Thus, the ratio L1/L2 = 1.08.

   (iii) Seated height L3 to minumum value.

   (iv) Anterior arm length L4 to minimum value.

   (v) Bideltoid breadth L5 to minimum value.

   Record all of the above values.

5. Place the occupant in the seat and locate the thigh on, or above, the seat cushion. As necessary, increase L1 so thigh clears the seat cushion. Increase L2 accordingly in order to maintain ratio L1/L2 = 1.08.

6. Place the right foot on the right rudder pedal in the full rudder position (if it will reach). If it will not, position the foot at pedal height and while keeping L1/L2 ratio at 1.08, increase L1 + L2 until pedal is contacted (P2). If L1 or L2 exceed maximum before pedals contacted, they cannot be reached in this seating/rudder pedal configuration. To re-attempt, select new initial configuration.

7. With the right foot position fixed, and if leg angle is less than 20 degrees, increase L1 and L2, keeping L1/L2 at 1.08, until 20 degree requirement is achieved (P3). Record the values of L1 and L2. If L1 or L2 exceed maximum, 20 degree angle cannot be achieved in this seating/rudder pedal configuration.

8. Position the left foot on the left rudder pedal.

9. Check that neither leg interferes with any of the cockpit interior surface.

10. Simultaneously move the right foot rearward and the left foot forward by equal amounts. Check for any interference with the cockpit interior. The magnitude of this adjustment is dependent on the total amount by which the pedals can be adjusted, the number of increments considered necessary between the extremes and computing power and CPU time available. While maintaining the same values for L1 and L2, continue to increment the left and right foot positions over the full range of pedal adjustment for the given configuration. Check for interference with the cockpit interior. If a condition of marginal interference occurs, the full range of pedal movement cannot be achieved by this individual in this seating position.

11. If no interference occurs, decrease L1 by 1 cm (or more or less as the particular seating configuration would seem to dictate) and increase L2 by the appropriate amount so as to maintain the required leg flexion angle. If L2 reaches its upper limit, it should be held constant at that value while L1 is decreased. Repeat step 10 and continue to repeat both steps 10 and 11 until a marginal interference occurs or until the ratio L1/L2 becomes less than its minimum value. Record the values of L1 and L2 (P4).

12. Return L1 and L2 to position P3.

13. Increase L1 by 1 cm (or whatever value seems appropriate for this seating configuration) and decrease L2 by the appropriate amount so as to maintain the required leg flexion angle. If L1 reaches its upper limit, it should be held constant at that value while L2 is decreased. Repeat step 9 and continue to repeat both steps 10 and 13 until a marginal interference occurs or until L1/L2 exceeds its maximum value.

    Record the values of L1 and L2 (P5).

14. Return L1 and L2 to position P3.

15. While maintaining L1/L2 ratio at the initial value of 1.08, increase L1 + L2 by 1 cm (or whatever seems appropriate for this particular seating configuration). Note the angle the lower leg subtends with the upper leg. Repeat step 10.

16. Maintaining the angle observed in 15 (the new required leg flexion angle), repeat steps 11 through 15 while noting that for every simultaneous increment of L1 + L2, a new position P3 is created. Repeat this procedure until a marginal interference occurs (P6), L1/L2 exceeds limiting values (P7,P8), or either L1 or L2 exceed limiting values. Record all values of L1 and L2.

Figure 1a illustrates typical L1 and L2 manipulations.

Figure 1b illustrates the Leg Clearance Envelope.

Figure 2a illustrates a flow chart outlining the Upper Leg Clearance Analysis Procedure for Ejection Aircraft.

Figure 2b illustrates a flow chart outlining the Leg Clearance Analysis Procedure.

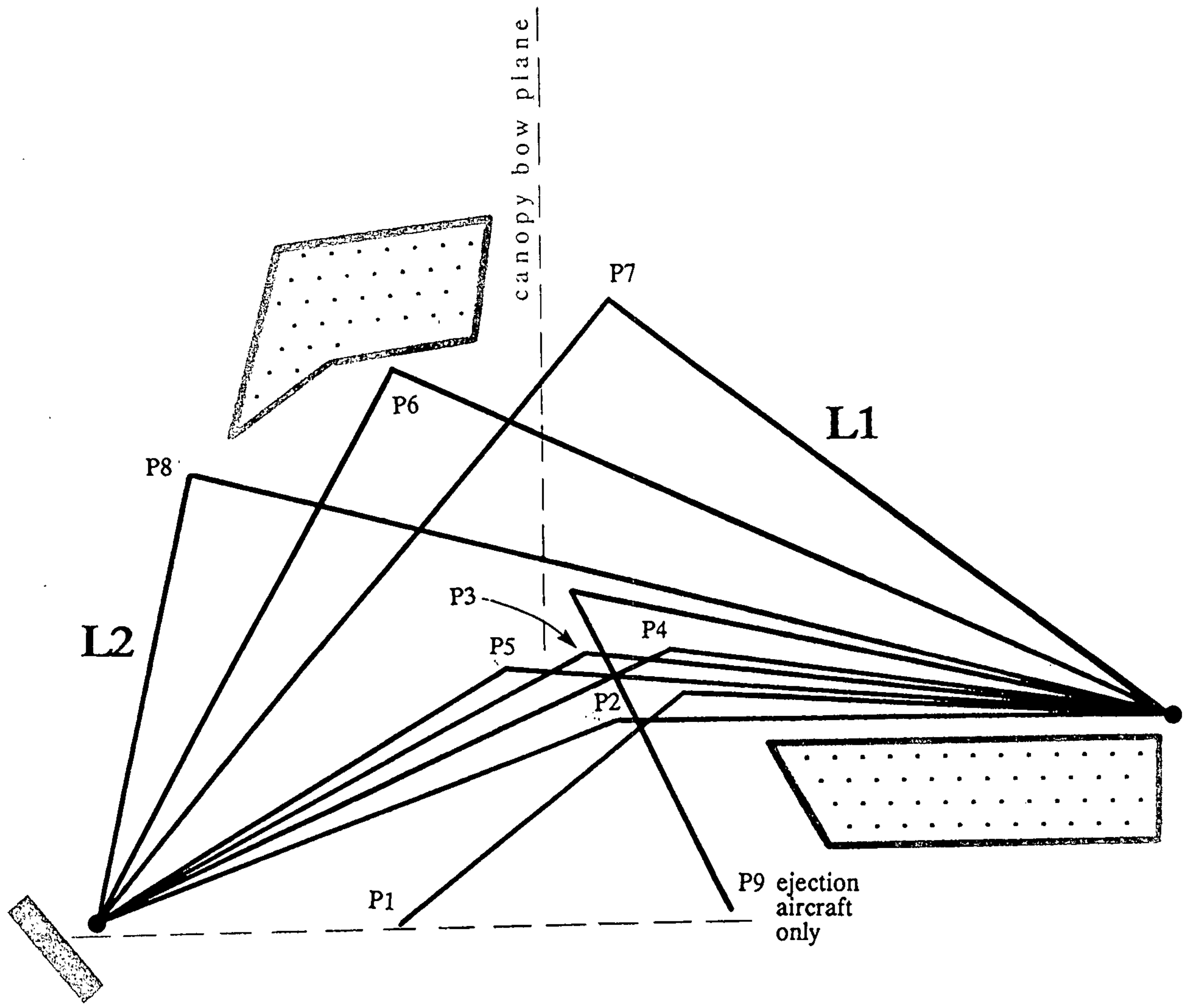

Figure 1a: Leg Clearance

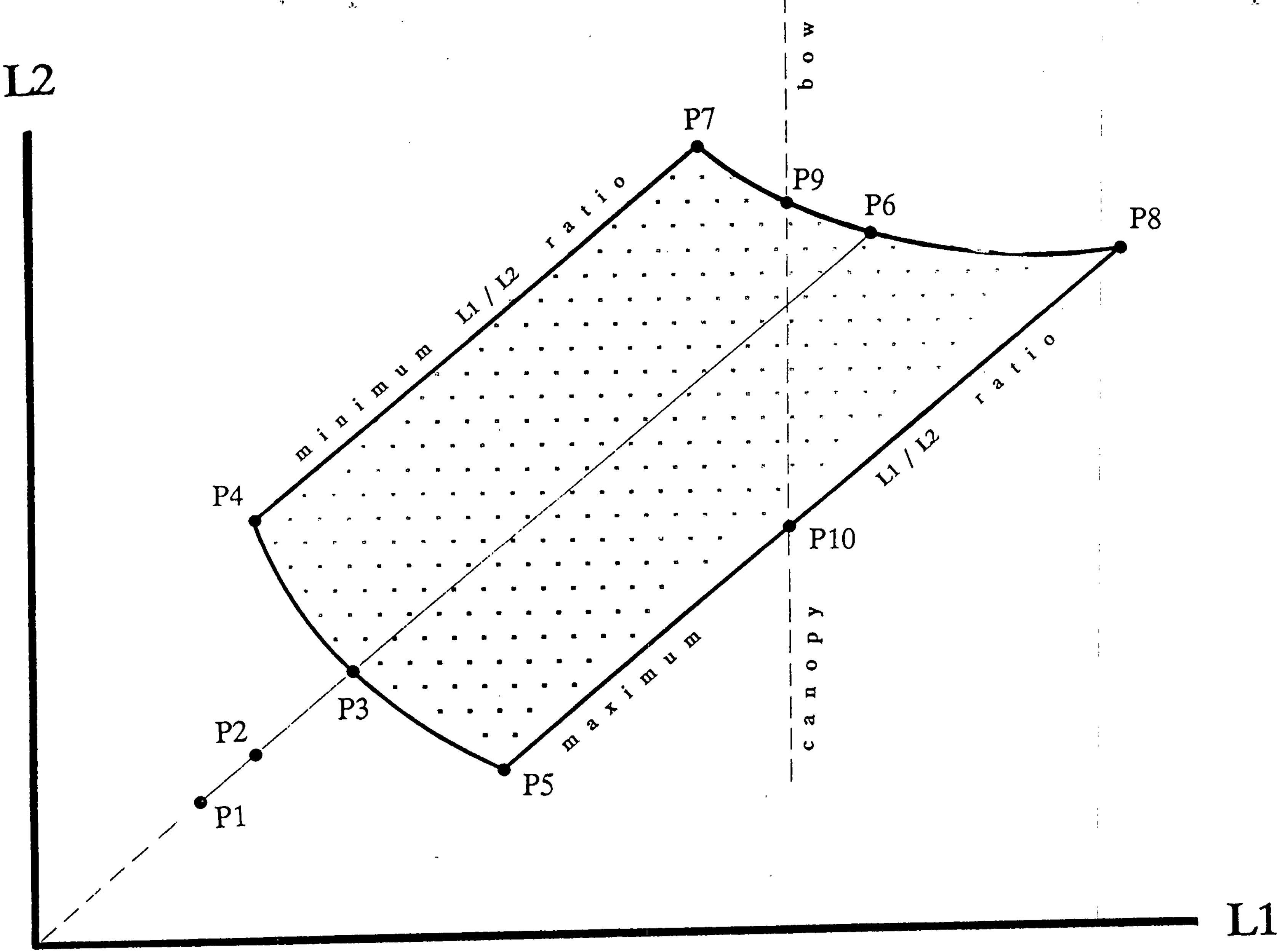

Figure 1b: Leg Clearance Envelope.
These envelopes are hypothetical in nature. The true envelopes will likely comprise many irregular surface boundaries due to the complex crew station environment.

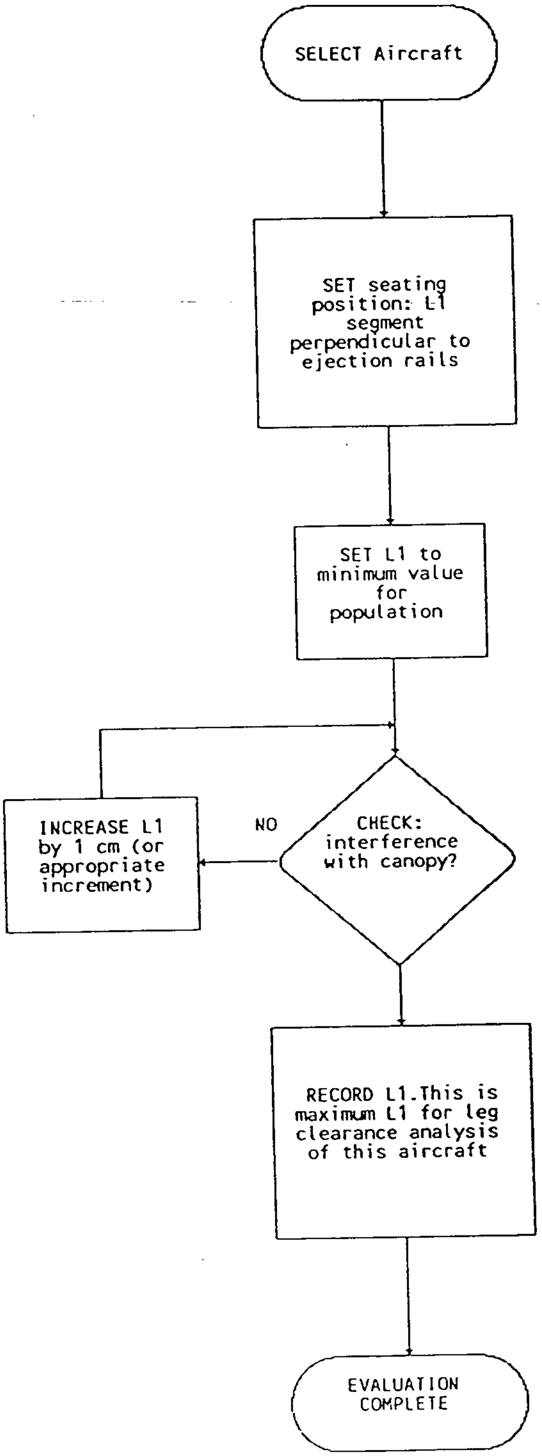

Figure 2a: Upper Leg Clearance Analysis Flowchart

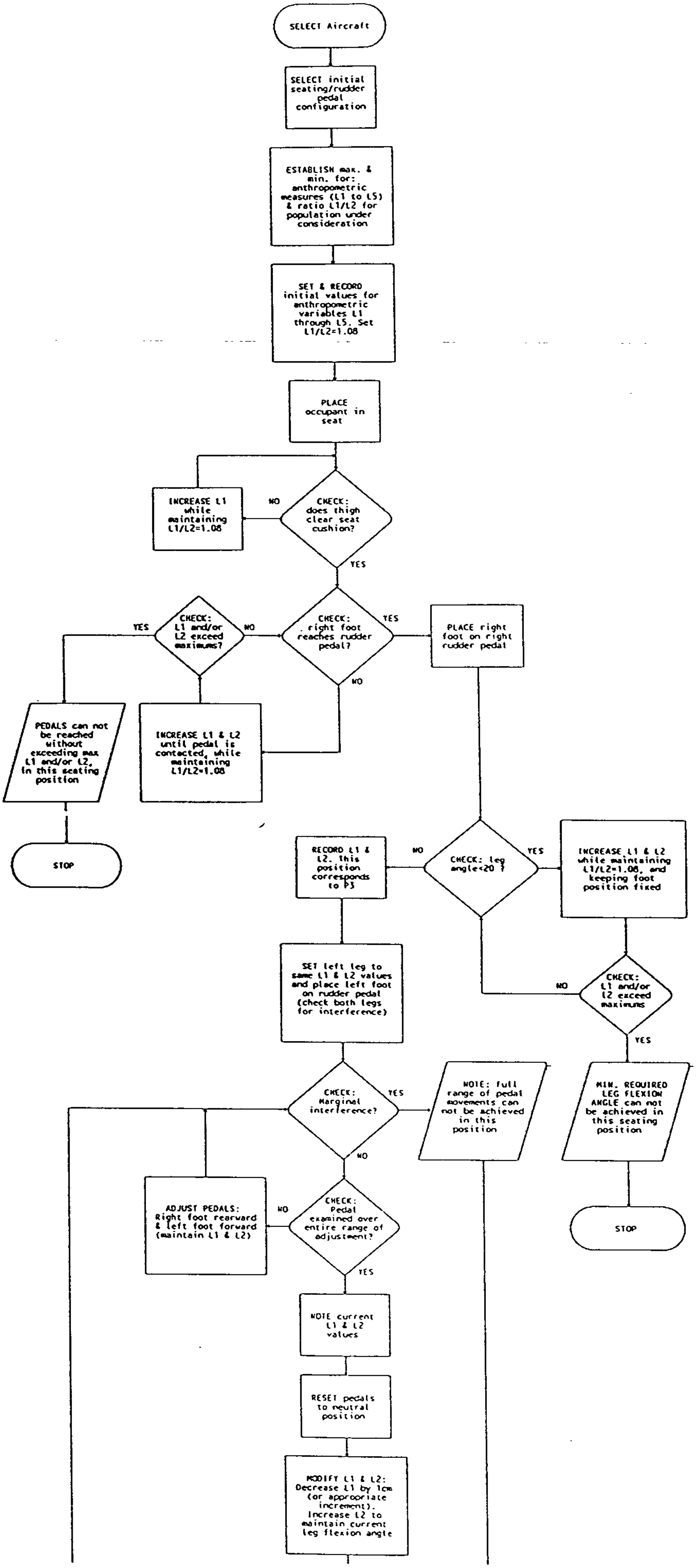

Figure 2b: Leg Clearance Analysis Flow Chart

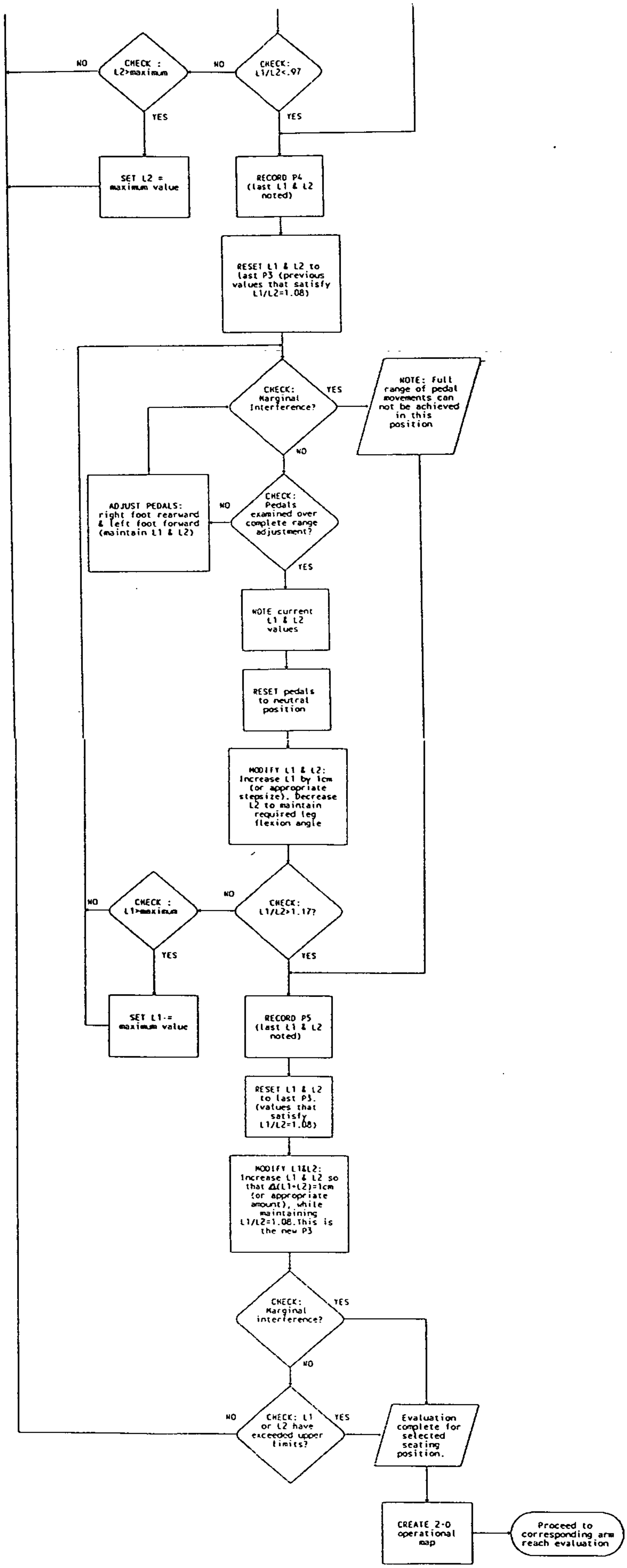

Figure 2b: Leg Clearance Analysis Flow Chart (cont'd)

3.2.2 Vision and Arm Reach Evaluation

The vision and arm reach evaluation is performed with the occupant placed in the same initial seating configuration as for the leg clearance evaluation. Similarily, subsequent evaluation and interpretation can only be accomplished with modified seating positions corresponding to those used in the leg clearance evaluation procedure.

The procedure for vision and arm reach evaluation is outlined below.

All adjustments to segment lengths shall be in 1.0 cm increments. This value has been arbitrarily selected and represents only a suggested increment. Larger increments would require less iterations although there would be an accompanying loss of process resolution.

1. Alter sitting height L3, if necessary, so that minimum visual requirements are marginally met (P11 - see Figure 3). Record the value of L3.

2. Set anterior arm length L4 and bideltoid breadth L5 at minimum.

3. Increase anterior arm length L4 until reach requirements are marginally met (P12). Record this value of L4 as the minimum permissible anterior arm length (P12) for the corresponding bideltoid breadth L5 at the lower limit of vision (P11).

4. Increase bideltoid breadth until lateral clearance requirements are marginally met or bideltoid breadth reaches the maximum selected value or a physical limitation within the workstation (P13 - see Figure 3). For each increment of bideltoid breadth, determine the minimum anterior arm length (step 3) required to meet marginal reach requirements. Record all values of L5 and corresponding anterior arm lengths L4. The largest value of L5 represents the maximum permissible shoulder width (P12) at the lower limit of vision (P11).

Evaluation of ejection seat aircraft crew stations will represent a special case in that the maximum bideltoid breadth is limited by the width of the ejection opening of the canopy.

5. Increment seated height L3. For each increment of L3, determine minimum anterior arm length L4 (P14). As well, for each combination of L3 and L4, determine the maximum bideltoid breadth L5 (P15). Continue increasing L3 and monitoring L4 and L5, until the seated height equals the maximum visual height limits or canopy clash with the helmeted head occurs or 99th percentile value for seated height is reached (P16). Record all values of L3, L4 and L5.

Figure 3 illustrates process steps P11 through P16.

Figure 4 illustrates a flowchart outlining the Vision and Arm Reach Evaluation.

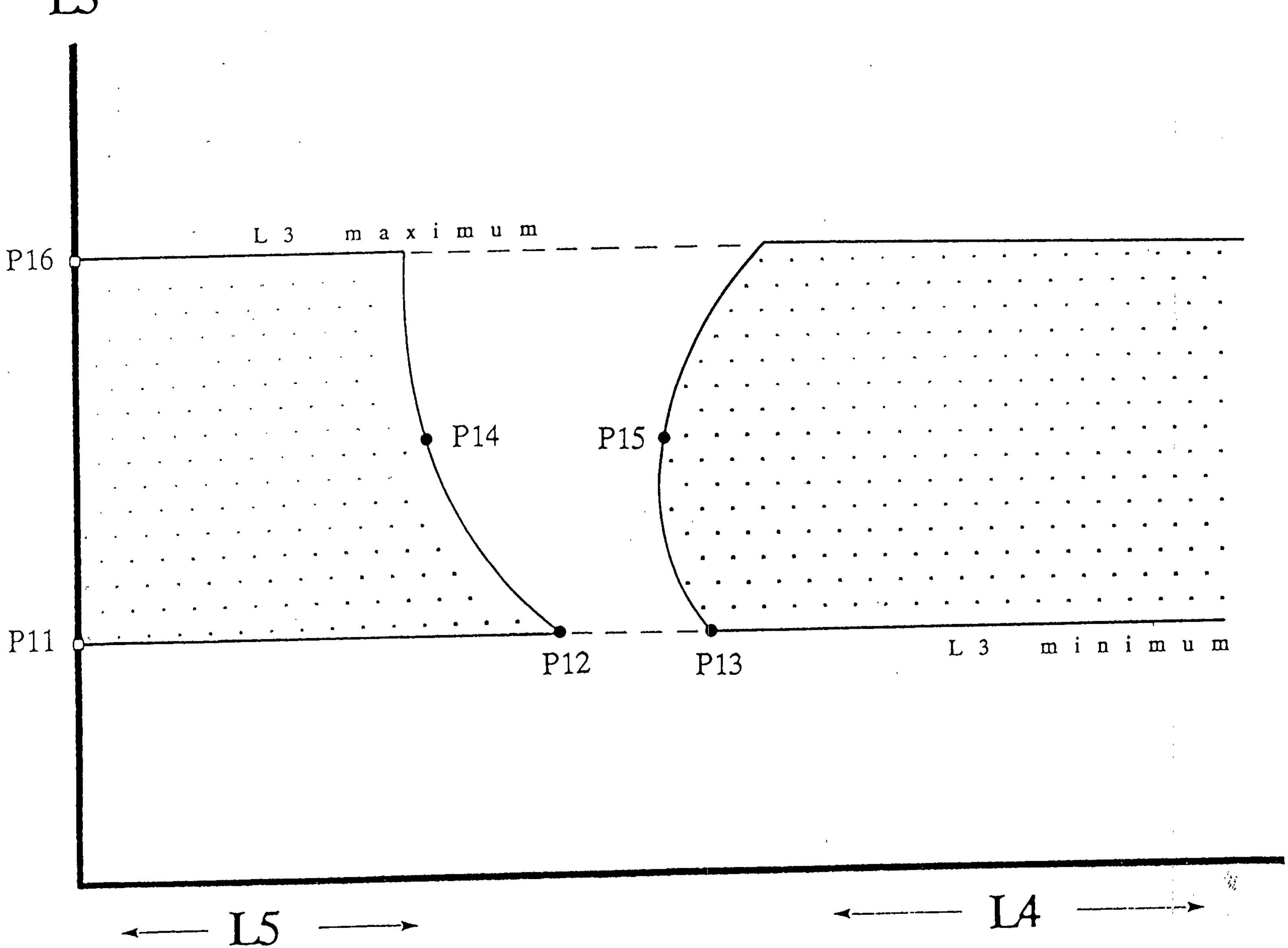

Figure 3: Bideltoid Breadth and Arm Length Envelopes.
These envelopes are hypothetical in nature. The true envelopes will likely comprise many irregular surface boundaries due to the complex crew station environment.

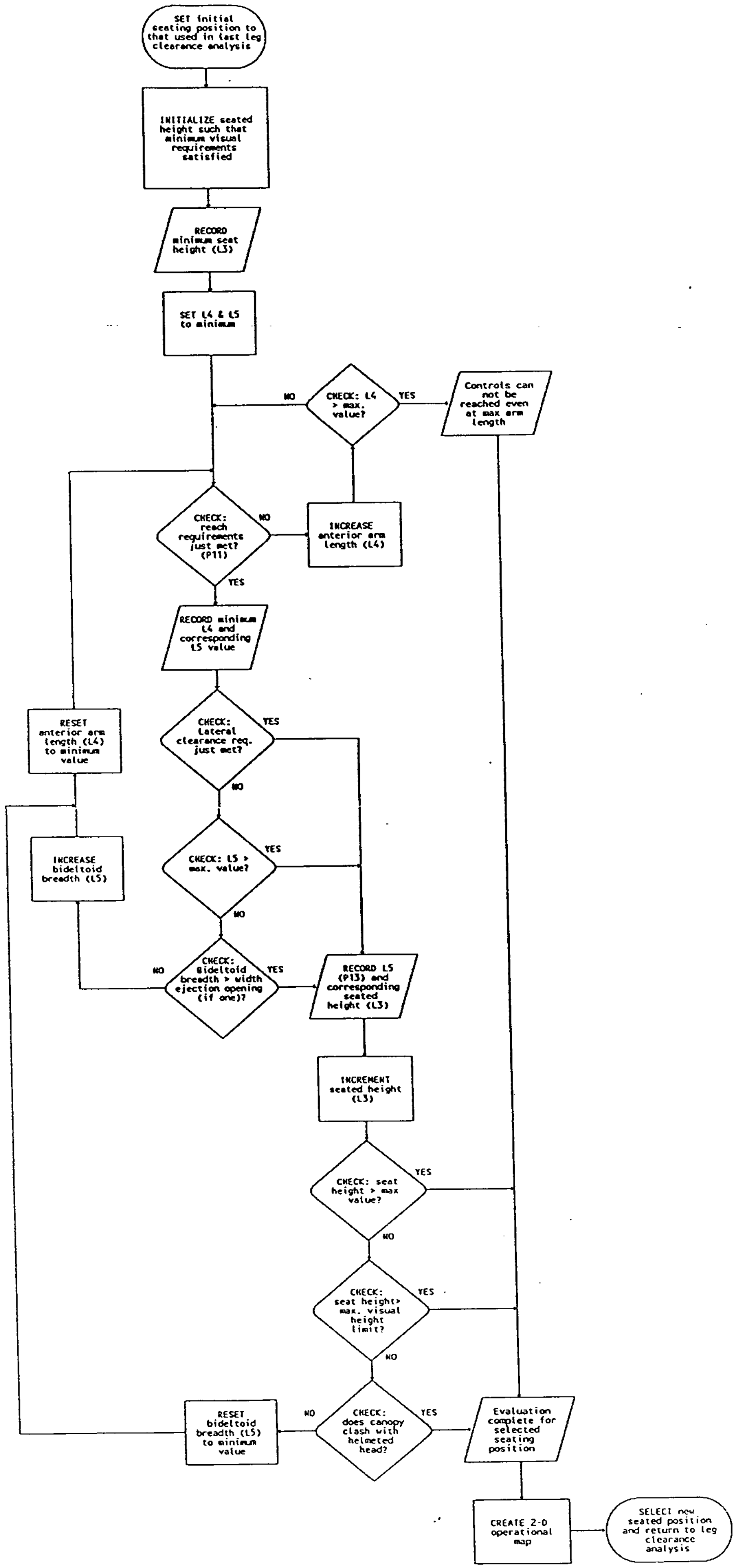

Figure 4: Vision and Arm Reach Flow Chart

3.3 Analysis of Results

This revised process establishes three separate envelopes representing the clearance, reach and visual criteria for a given seat and rudder pedal/foot configuration. Figure 5 illustrates how these envelopes can be mapped together to provide operational limits for the given seating configuration. In a fixed seat aircraft with fixed rudder pedals, these envelopes would represent the complete operational envelope. Adjustable and ejection seat aircraft evaluation would require that the process be repeated for other rudder pedal positions and other seat locations. The number of different crew station configurations that must be considered should be a function of the particular aircraft design.

Crew stations that are small and of highly irregular geometry would likely require that between the extremes of seat and pedal positions, a greater number of permutations and combinations be examined.

It is recommended that the minimum acceptable number of configurations for fully adjustable seats be three rudder pedal positions, three seat heights and three fore/aft seat positions resulting in 3 x 3 x 3 = 27 variations. The minimum acceptable number of configurations for ejection seat aircraft would be 4 rudder pedal positions and three seating positions resulting in 4 x 3 = 12 variations. These configurations represent the fewest number of configurations or operational maps that will accurately define a given workstation. Additional configurations will increase the resolution and accuracy of the process. When, for each aircraft, all of the necessary operational maps have been generated, the aircrew selection process is merely an investigation as to whether the candidate fits into one or more of these maps.

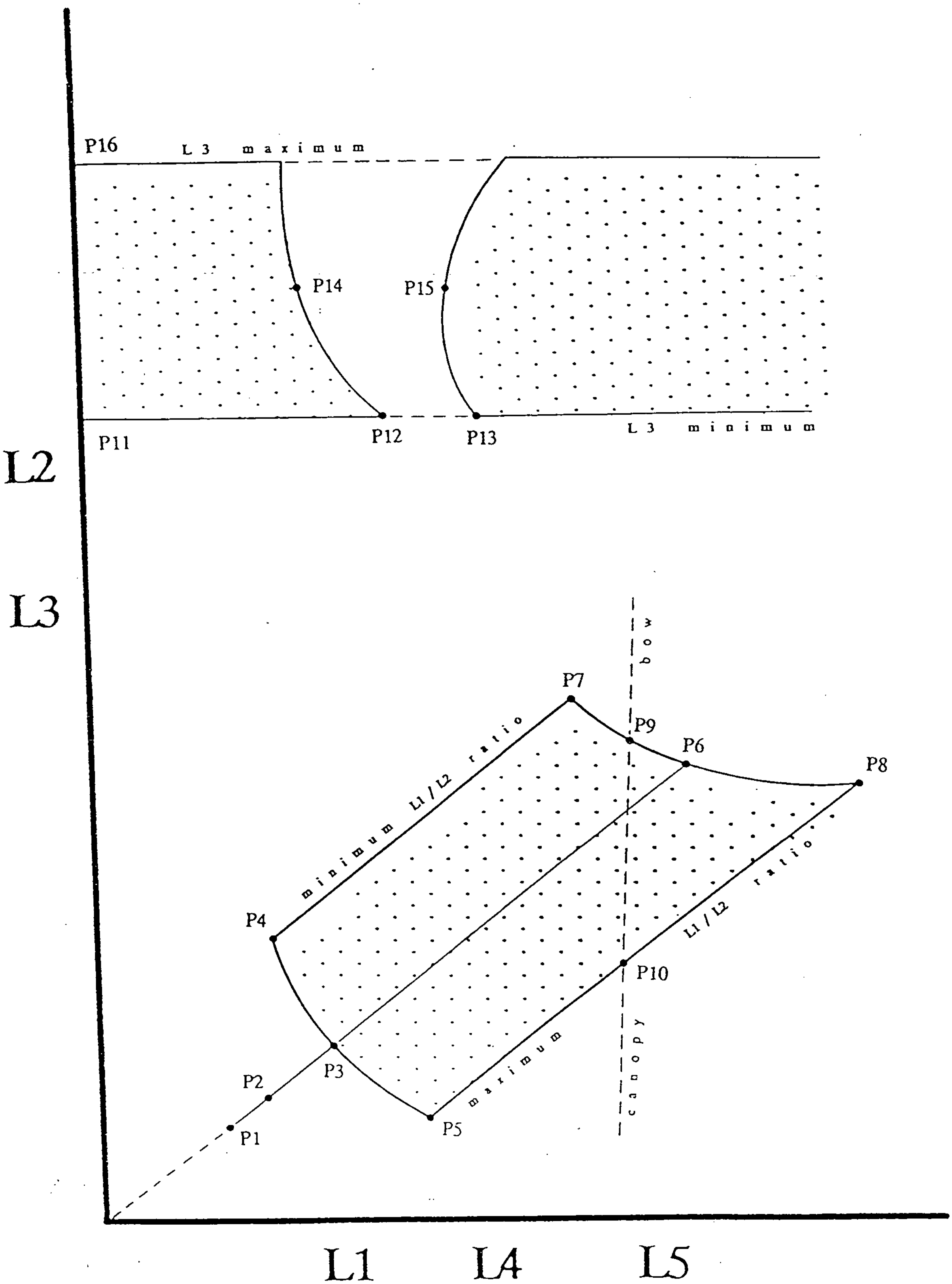

Figure 5: Reach/Clearance/Vision Envelopes

The aircrew selection process is outlined below:

1. Select the particular aircraft.
2. Measure L1, L2, L3, L4 and L5 of the candidate.
3. Exclude all maps that do not satisfy L1 and L2 requirements.
4. Exclude all maps for which L3 (seated height) is out of range.
5. Exclude all maps for which L4 (anterior arm length) is too small.
6. Exclude all maps for which L5 (bideltoid breadth) is too large.

The candidate's anthropometric measures must be within all three envelopes presented on the composite map. If one or more maps remain, he/she will fit in that particular aircraft.

The above process enables the pre-selection of a crew member but does not characterize the nature of the crew station environment. In order to do so, all of the maps for a given aircraft are superimposed upon each other. This would yield for this composite "map" three types of zones or regions. Type I zone is where "all" the allowable regions overlap each other. Type II zones are those regions where portions of some maps overlap each other. Type III is that region where all disallowable regions of each map coincide. For any aircraft, the "zones" on the composite map represent ranges of anthropometric variables where aircrew candidates:

I) will fit
II) might fit
III) will not fit

In the absence, for the present exercise of detailed aircrew station geometry, it is not possible to determine the practical usefulness of this method. However, in principle, it does provide a rational means to characterize different aircraft crew station geometries in terms of five specific anthropometric parameters.

4.0 REFERENCES

1. ASCC Air Standard 10/53E, Air Standardization Co-ordinating Committee Vision Requirement Standards.

2. Matthews, B.G., Greaves, K.F. and Rothwell, P.L., "Evaluation Process for the Assessment of Aircrew/Cockpit Compatibility Using SAMMIE". Unpublished student workterm report, Downsview, Ontario: DCIEM., 1985.

3. Matthews, B.G. and Rochford, S.L., "An Evaluation of the CAD System SAMMIE". Unpublished student workterm report, Downsview, Ontario: DCIEM, 1986.

APPENDIX 'A'

Work Statement

Introduction

DCIEM has been tasked to review Canadian Forces (CF) aircrew anthropometry and aircraft cockpit geometry, and to make recommendations to ensure that CF aircrew selection standards are compatible with current and future cockpits (1). Among the specific objectives of the tasking, DCIEM is required to (a) propose a process to determine physical incompatibilities of aircrew with aircraft crew stations, (b) report the current status on physical compatibility of CF aircrew with CF aircraft, and (c) review current selection standards and recommend required changes.

There are several methods of assessing aircraft cockpit geometry and potential aircrew incompatibility. For this tasking, three-dimensional computer man-modelling has been selected as the primary assessment tool. The technique offers several advantages over other candidate assessment methods. It permits the anthropometric representation of individual or population data, using absolute values or percentile equivalents. As well, its analytical capabilities to assess reach, body clearances, and vision inside and outside the aircraft are superior (2).

To use a man-modelling computer aided design (CAD) system effectively, data on the anthropometry of the population, the geometry of the workplace and the tasks affected by the first two factors are needed. The necessary data have been gathered through an anthropometric survey of CF aircrew, aircraft measurement sessions and interviews with experienced pilots and navigators.

The process that has been developed for determining physical incompatibilities of aircrew with aircraft crew stations involves a step-by-step evaluation using man-modelling CAD. The rationale used to establish the process assumes that aircrew will be selected to fit the aircraft in the CF inventory, not that the aircraft will be modified to suit the aircrew. In general terms, the process determines the limits dictated by each crew station by focusing on the manipulation of anthropometric variables that effect body clearances, capabilities of vision in and around the workspace, and arm and leg reaches. The process should yield ranges of acceptable body dimensions or combinations of dimensions as indicators of the physical requirements of each aircraft.

An independent review of the proposed evaluation process is required to verify the soundness of the approach. The outcome of the review will indicate whether additional work is necessary. The purpose of this contract is to critique the proposed process with respect to the following: considerations of other approaches to similar problems (e.g. use of multi-variate statistics), appropriateness to determine physical limitations imposed by each aircraft crew station, and suitability to identify the current status of CF aircrew/cockpit compatibility. The contractor will be required to recommend alternative courses of action, based on the results of the review.

Statement of Work

To assess the evaluation process, several issues must be considered. These include the input data used, the expertise required of the evaluator, and the way the output data are to be interpreted. Therefore, it is necessary that the contractor identify and become familiar with background information considered relevant to the development of the evaluation process. This information includes the following: current CF selection criteria (3,4), 1985 CF aircrew anthropometric survey results (5), general physical characteristics of CF aircraft, aspects of physical accommodation being considered, and the analytical capabilities of the SAMMIE program (6). Much of this information can be provided by the Scientific Authority.

After reviewing the proposed process with respect to the background information, the contractor shall be required to recommend whether or not the process satisfies the objectives of the tasking. If the proposed process is determined to be adequate, the contractor will make recommendations for any necessary improvements to the process and develop a protocol for the implementation of the process. If the proposed process is found to be inadequate, the contractor will be required to recommend the steps that should be taken to develop an alternative process. Either course of action must be supported by the results of the review.

Based on the above considerations, the contractor will undertake the following work.

- Identify and review background materials considered relevant to the development of the evaluation process.
- Discuss process requirements (with respect to background information) with the Scientific Authority.
- Critique the proposed process and provide a written report on the following: relevant input data requirements, expertise required of reviewer, anticipated outputs, and relevance of outputs to the objectives of the tasking as discussed with the Scientific Authority.
- Prepare and submit recommendations either that support the implementation of the proposed process or that support the development of a preferred process to study aircrew/cockpit compatibility.

Travel and Expenses

Regularly scheduled meetings with the Scientific Authority will be necessary. Therefore, any associated travel needs anticipated by the contractor should be specified. All travel will be done under Treasury Board regulations. No travel will be done without the prior consent of the Scientific Authority.

In response to the Request For Proposal (RFP), the contractor must describe his approach to the Statement of Work (SOW). He must demonstrate a thorough understanding of anthropometry and its relevance to workplace accommodation. A description of the qualifications and capabilities of personnel who will be involved in the project, as well as a description of previous work in a similar area, must be included.

Per diem or hourly rates as applicable must be indicated for professional, technical and clerical staff. The number of days work required must also be indicated for all staff. A forecast of all other foreseeable expenses must be included.

Timing and Milestones

The work schedule will be determined by the contractor and commence with a familiarization briefing at DCIEM. The contract will meet a final completion deadline of 4 months after commencement. Progress reports shall be forwarded to the Scientific Authority at the end of week two, month one and month two, after commencement of the contract. A review meeting will be held when all contract activities have been completed. A draft copy of the final report will be prepared and submitted to DCIEM before the end of month three of the contract period. Ten copies of the final report will be delivered no later than the end of the fourth month.

Deliverables

The selected work program will be monitored by the Scientific Authority. Monthly progress reports, prepared by the contractor, shall consist of a narrative of approximately one (1) page describing the progress achieved in terms of the SOW. It shall explain any variations in the work or expenditure plan, specifying any problems encountered or foreseen (relating to time, cost or technical matters) and any other matter considered reportable by the contractor. The final report, which must be approved by the Scientific Authority, shall address all items outlined in the SOW.

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1. L6640-4 (DAR 3-2) dated 7 December, 1982. Aircrew Anthropometry Tasking.
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3. STEWART, L.E. 1985 Anthropometric Survey of Canadian Forces Aircrew. DCIEM Contract Report, December 1985.
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5. CANADIAN FORCES ADMINISTRATIVE ORDER 34-44. Selected Anthropometric Parameters. CFAO 34-44 (Annex A, Appendix 1), October, 1978.
5. PYE, D. SAMMIE Reference Guide. DOC 9515-2LA, Prime Computer Inc., Natick Mass.

APPENDIX 'B'

Anthropometric Considerations

ANTHROPOMETRIC DATA

Human anthropometry is the science that deals with the measurements of weight, size and proportions of the body and its segments. The importance given in recent years for the development of proper selection criteria for a given job and/or task, has created the need for a branch of knowledge called "Occupational Biomechanics".

According to Chaffin and Andersson (1984): "Anthropometric data are fundamental to Occupational Biomechanics. Without it, biomechanical models to predict human reach and space requirements cannot be developed". Based on this statement and on a good functional understanding of anthropometrics, it is evident the "System for Aiding Man/Machine Interaction Evaluation (SAMMIE)" must be supplied with the proper anthropometric data.

Proper anthropometrics for SAMMIE modelling should not be restricted to segment link lengths, but should also include:

- body segment volumes which may be important for the clash module; and
- range of motion data which may be important in determining maximal arm and leg reach.

To be meaningful, body-segment link lengths and range of motion should be available from the same subjects.

Since the model is to be used to determine if a given individual has the proper anthropometric characteristics to be a pilot, it is necessary to fill SAMMIE's data bank with measurements from the general adult population. Using only the actual CF data could be restrictive. For the purpose of representativeness, one could compare the CF data to other population data, eg. American, British, French, etc..

To determine maximum functional arm and leg reach, it is important to consider:

(a) the exact length of each segment form bone landmarks;

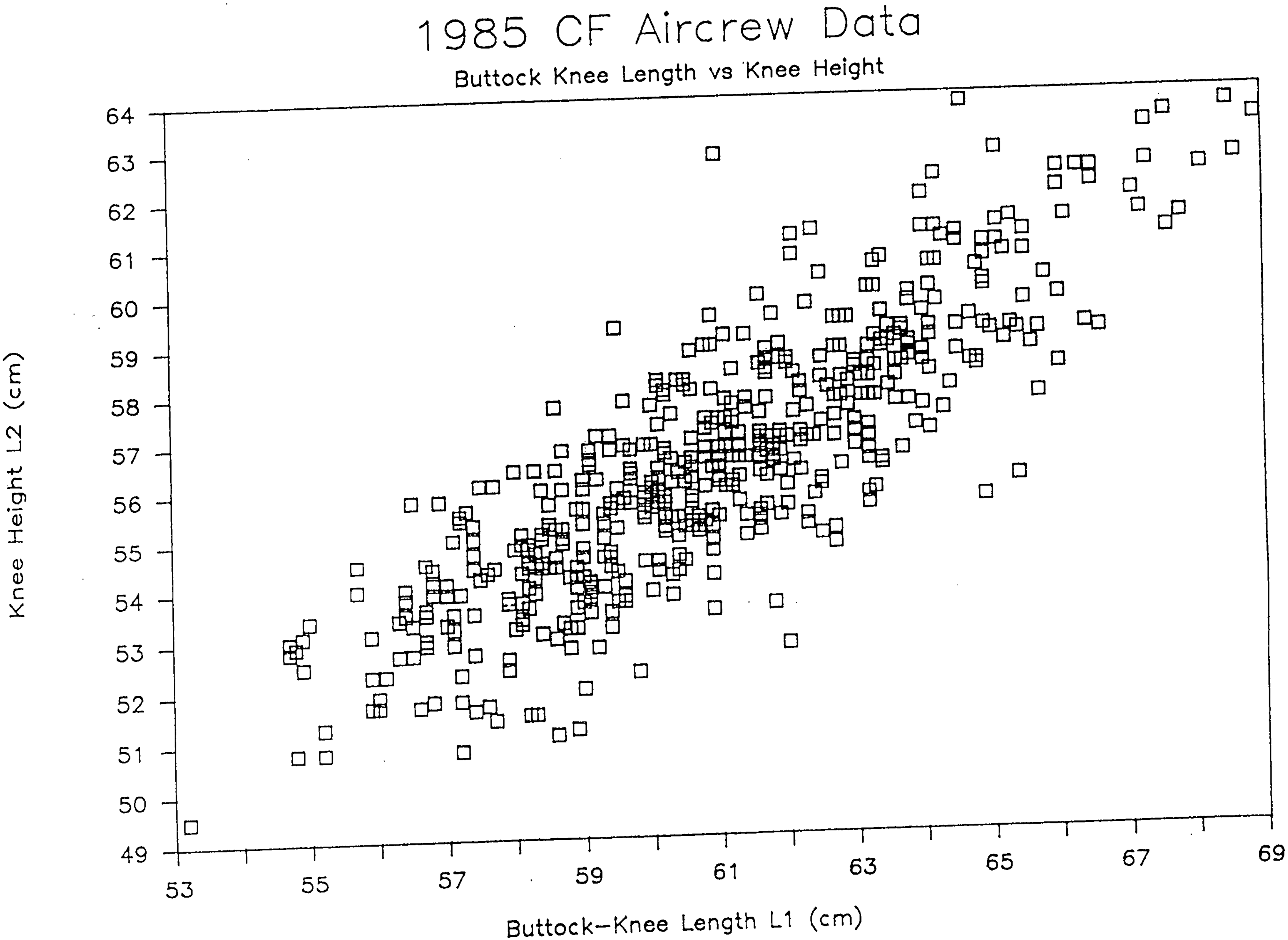
(b) the range of motion of the articulations taken into account the 20^{0} angle needed for maximum strength;

(c) the contribution of other articulations from the supportive structure.

For example, in the man model, the arm reach variable is dependant on the flexibility of the shoulder joint and on the other joints of the shoulder girdle. The extra arm reach will be made possible through the flexibility of the acromioclavicular, the scapulocostal, the sternoclavicular, the costosternal and the costovertebral joints. As for determining maximum leg reach, it is necessary to consider the possible contribution of the pelvis rotating around the vertical axis as well as ankle plantar flexion.

APPENDIX 'C'

Anthropometric Aircrew Data


1985 CF Aircrew Data
Buttock Knee Length vs Knee Height
Knee Height L2 (cm)
Buttock-Knee Length L1 (cm)
64
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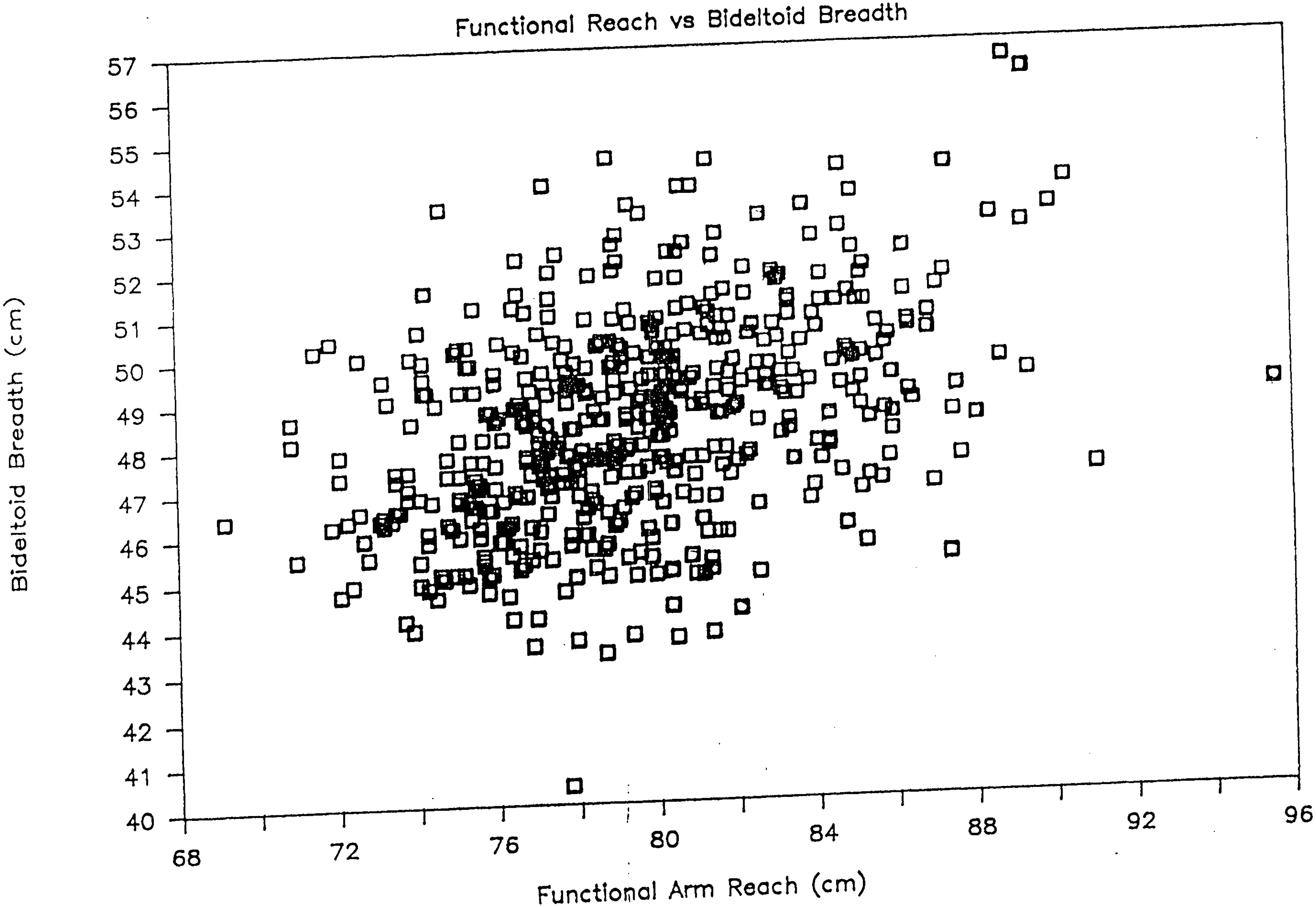
1985 CF AIRCREW DATA



APPENDIX 'D'

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